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# Blended Rotor-Spun Yarns with a High Proportion of Flax

## Abstract

We present the results of tests on rotor-spun blended yarns, made with a high proportion of flax, and rotor-spun all-cotton yarns. Of special concern was the method of preparing the fibres and sliver. The flax/cotton sliver was made up of medium-long cotton, and the flax fibre was shortened and reduced in diameter by mechanical cottonising. The basic composition of the flax/cotton sliver was 30% cotton and 70% mechanically cottonised flax. The optimum linear density of the yarns was 40 tex. The experiments enabled the optimum values of twist and linear density to be found, at which the quality parameters of the yarns produced were acceptable. In addition, a comparative analysis of the produced cotton yarn and flax/cotton yarn was made. The flax/cotton yarn with a high proportion of flax is suitable for both weaving and knitting.

**Key words:** flax cottonised fibres, cotton, blends flax/cotton rotor-spun yarns, yarn properties, application of blend flax/cotton yarns.

72/P-04653, PN-72/P-04654, and PN-72/P-04652, describing the test methods.

## Characteristics of the raw materials used in the blends

A comparative analysis was made of the results of spinning cotton (100%) and flax/cotton blends (containing a high proportion of cottonised flax). It was found that compared to the cotton yarns, the blended flax/cotton yarns were characterised by a lower strength (by about 10%) and slightly higher CV values of linear density and strength. In addition to that, a higher twist factor (by 10 - 12%) was required for a smooth spinning process.

Despite these differences, the blended yarns meet the standard quality requirements for this group of products [1, 3, 5, 6].

The level of breakage was determined at random, and was estimated at the following levels:

- for blended yarns: 95 to 160 breaks per 1000 hours,
- for cotton yarns: 65 to 85 breaks per 1000 hours.

In the rotor-spinning system, cotton can only be blended with cottonised flax (Figure 1). Of the available types of flax fibre, practically only one is used as an 'input' material in the production of cottonised flax. This material is the flax hackling noil. It is a fibre deriving from the central parts of the stem, the origin of most of the technical fibres and fibres that are very clean (showing only traces of shive). The fibres (noil) are used for relatively coarse yarns produced by the linen spinning system.

If the flax hackling noil is subjected to cottonising, it takes a form and shape that permit its processing in a blend with cotton by the cotton (rotor-spinning) system. The important properties here are the linear density and staple length of the cottonised fibre. In the spinning results discussed here, the material was mechanically cottonised flax.

## Introduction

For many years Zamutex of Łódź (specifically the Moszczenica plant thereof) has been co-operating with the Institute of Natural Fibres, Poznań, in the manufacture of blended rotor-spun cotton/flax yarns. This co-operation has contributed to the development of a technology for manufacturing a yarn made from 70% mechanically cottonised flax in blend (before processing) with cotton, and the use of this yarn for woven and knitted fabrics and other textiles which are currently regarded on the market as being ecologically-friendly. Flax (as well as hemp) has high utilitarian and ecological values, being

- antiseptic (bacteriological, antifungal),
- absorbent,
- physiologically friendly (hygroscopic, thermal, and electrostatic properties), and
- protective against UV radiation.

This paper presents the results of the rotor spinning of yarns of 30, 40, 50, 60 and 80 tex, using flax/cotton blends with a high proportion of mechanically cottonised flax of 70% flax / 30% cotton in blends for all the above-mentioned linear densities. We also give the physical and mechanical characteristics of the components of the blends. For comparison, we also present the results of the rotor spinning of cotton alone within the above-mentioned linear density range (30, 40, 50, 60 and 80 tex).

All tests were carried out in accordance with the BN-75/7531-01 Standard general specification, and with standard PN-



**Figure 1.** Distribution of fibres in the cottonised flax, mean fibre length – 27.4 mm, fibre linear density – 1.1 tex.

As a result of the cottonising operations, a cottonised flax with the following characteristics was obtained:

- linear density of fibre – 0.7 to 2.0 tex
- mean length of fibre – 18 to 35 mm
- content of fibres 40 - 50 mm long – about 8%.

An example of cottonised flax is presented in Figure 1.

The middling Uzbekistan cotton with the following parameters was blended with the flax:

- fibre linear density – 0.162 tex
- classification length of fibre – 33 to 34 mm
- total faults and impurities – 3.2%

In respect of length and fineness, the elementary fibres of flax (ultimates) are close to cotton (Table 1). They are elongated, spindle-shaped, and have a polygonal cross-section (usually pentagonal); there is a channel inside each ultimate. On the other hand, a cotton fibre has a different shape, of a flat twisted ribbon, owing to which it has a greater spinning capability. In addition to that, the cotton fibre is a unicellular fibre, while the flax fibre is multi-cellular, at least in the form it appears in cottonised flax. The individual fibres in cottonised flax are composed of a few to several elementary fibres. The cotton fibre is a few times finer than cottonised flax [2, 4].

Technological conditions for manufacturing blended cotton/flax yarns by the cotton rotor-spinning system [1]

1. Preparation of cottonised flax (hemp) before blending with cotton:
  - emulsifying (wax OT78 – 0.5% at a humidity of 20%);
  - seasoning: 24 - 48 hrs.
2. Formation of blend (cotton/flax, opening on an opening/mixing (willow-type) set, ageing in chamber at 80% humidity, 18 °C).
3. Seasoning – about 48 hrs, with manual mixing every 8 hours.
4. Second opening and mixing on willow.
5. Formation of lap on an opening/cleaning set, MT type.
6. Carding on a flat card CZ 693 (suitably adapted – replaced clothing on card cylinders and flats).
7. Doubling of card slivers on Rietter Laksmi draw frame.
8. Evening-up of slivers on a Rietter RSB951finisher draw frame.
9. Spinning on BD200RN rotor spinning machine (with replaced spinning heads).

**Table 1.** Characteristics of selected properties of flax and cotton.

Yarn properties	Unit	Flax	Hemp	Cotton
Length of technical fibre	cm	20-140 (mean 50)	80-300 (mean 120)	-
Length of elementary fibre	mm	1-130 (mean 13-40)	5-55 (mean 15-25)	10-70 (mean 12-36)
Tenacity of fibre	cN/tex	mean 53	mean 57	mean 30
Linear density of technical fibre	tex	mean 2	mean 2.2	-
Linear density of elementary fibre	mtex	mean 290	mean 333	mean 143-200

**Table 2.** Quality parameters of the rotor-spun flax/cotton yarns with a high content of cottonised flax (70%).

Linear density of yarn		Coefficient of variation		Tenacity, cN/tex	Twist, tpm	Twist factor $\alpha_m$
tex nom.	tex real	Linear density CV <sub>tex</sub> , %	Breaking force CV <sub>w</sub> , %			
30	31.5	3.3	12.7	8.1	966	171
	31.6	2.2	9.4	8.4	1034	184
	32.1	1.4	10.7	8.4	1054	189
	30.5	2.2	11.2	8.3	1040	185
	<b>mean</b>	<b>31.4</b>	<b>2.3</b>	<b>11.0</b>	<b>8.3</b>	<b>1024</b>
40	41.8	3.1	11.5	8.5	837	164
	39.7	3.5	12.3	9.8	868	173
	38.2	1.8	12.9	8.1	844	165
	40.0	1.3	11.6	9.4	813	163
	<b>mean</b>	<b>39.9</b>	<b>2.4</b>	<b>12.1</b>	<b>9.0</b>	<b>841</b>
50	52.3	1.3	7.7	10.1	688	157
	50.4	3.0	15.2	8.4	671	151
	49.1	2.2	12.1	8.2	690	157
	51.0	2.1	13.2	9.2	681	155
	<b>mean</b>	<b>50.5</b>	<b>2.2</b>	<b>12.1</b>	<b>8.7</b>	<b>683</b>
60	63.4	2.3	10.0	9.4	705	177
	61.0	2.8	14.2	7.6	734	181
	62.4	2.2	12.9	8.1	718	179
	61.0	3.8	12.7	8.0	749	186
	<b>mean</b>	<b>61.8</b>	<b>2.8</b>	<b>12.5</b>	<b>8.3</b>	<b>727</b>
80	79.0	2.6	14.3	8.2	629	178
	80.2	1.9	11.7	8.6	643	180
	81.3	1.3	10.5	10.6	517	147
	80.5	1.4	9.7	8.6	578	164
	<b>mean</b>	<b>80.3</b>	<b>1.8</b>	<b>11.6</b>	<b>9.0</b>	<b>592</b>

**Table 3.** Quality parameters of the rotor-spun cotton yarns.

Linear density of yarn		Coefficient of variation		Tenacity, cN/tex	Twist, tpm	Twist factor $\alpha_m$
tex nom.	tex real	linear density CV <sub>tex</sub> , %	breaking load CV <sub>w</sub> , %			
30	29.3	1.6	9.2	9.9	940	160
	29.7	1.2	11.4	8.7	873	150
	30.1	1.5	15.2	8.9	922	160
	30.5	2.2	13.7	8.2	931	163
	<b>mean</b>	<b>29.9</b>	<b>1.6</b>	<b>12.4</b>	<b>8.9</b>	<b>917</b>
40	39.1	1.5	10.5	9.9	796	157
	38.6	1.3	13.4	9.8	791	155
	38.9	1.4	10.8	10.6	750	148
	39.9	1.2	10.3	9.7	773	154
	<b>mean</b>	<b>39.1</b>	<b>1.4</b>	<b>11.3</b>	<b>9.9</b>	<b>778</b>
50	49.4	0.7	11.3	9.8	714	159
	48.9	1.8	10.9	10.2	637	141
	50.2	1.4	10.9	10.1	683	153
	49.2	0.8	13.0	10.9	659	147
	<b>mean</b>	<b>49.4</b>	<b>1.2</b>	<b>11.5</b>	<b>10.3</b>	<b>673</b>
60	59.8	2.1	11.7	9.2	621	152
	59.4	1.2	8.5	10.2	622	152
	59.7	0.9	12.4	10.0	652	159
	59.1	2.2	11.0	9.6	649	158
	<b>mean</b>	<b>59.5</b>	<b>1.9</b>	<b>10.9</b>	<b>9.8</b>	<b>636</b>
80	79.4	1.2	7.4	11.8	480	135
	81.0	1.9	9.5	10.7	518	147
	78.3	1.4	10.7	10.2	501	140
	81.1	1.7	8.7	9.8	488	139
	<b>mean</b>	<b>80.0</b>	<b>1.6</b>	<b>9.1</b>	<b>10.6</b>	<b>497</b>

### Results of rotor-spinning of flax/cotton blends with a 70% content of cottonised flax

The spinning of 20 lots of flax/cotton blends was carried out on a commercial

scale and monitored according to the technology described in the previous section of the paper. Yarns of linear densities 30, 40, 50, 60 and 80 tex were made. The process was regular, not exceeding the

allowable number of breaks occurring on the spinning frame. The number of turns per metre of the yarns was adjusted in spinning to the optimum breakage level over the spinning process itself.

The quality parameters of the yarns, presented in Table 2, meet the requirements of the relevant standard. This applies to both the strength and coefficients of variation of strength and linear density of the yarns. The yarns produced fully satisfy the requirements of weaving. The finest of the yarns, 30 and 40 tex, can be used for the production of knitted fabrics.

### Comparative rotor-spinning of cotton

Under comparable conditions cotton, was rotor-spun into 100% cotton yarns of linear densities 30, 40, 50, 60 and 80 tex. The quality indices of these yarns are presented in Table 3.

#### Comparative analysis of the results spinning of cotton and flax/cotton blends

On the basis of the data presented in Table 3, the diagrams a, b, c, d and e shown in Figure 2 illustrate the differences between the values of the quality parameters of the rotor-spun cotton yarns

and those of the yarns made from cotton-blended with mechanically cottonised flax in a large proportion.

A comparison of the quality parameters of the yarns shows that those made from cotton blended with cottonised flax generally have a slightly lower tenacity (by about 12%) than those made from 100% cotton, and that to ensure a correct spinning process, the number of turns per metre of the yarn must be increased by about 10% (at twist factor increased by 10 - 12%). Admittedly, the use of a higher twist in the case of the flax/cotton yarns results in a correspondingly lower efficiency of the spinning machine.

The coefficients of variation of strength and linear density are lower in the case of the cotton yarns, although they are confined within the standard tolerance.

The differences between the values of the respective parameters of the cotton and flax/cotton yarns are to the advantage of the former, which is because in the cross-section of a cotton yarn, there are many more individual fibres than in the corresponding cross-section of flax/cotton yarn. The number of fibres in the cross-section of a yarn has a determinant effect on its quality.

Let us compare the number of fibres in the cross-section of a 40 tex yarn:

- If the yarn is spun from 100% cotton of which the linear density is 0.16 tex, the number of individual fibres in its cross-section is 250;
- If the yarn is spun from a blend of 30% cotton and 70% mechanically cottonised flax with a linear density of 1.5 tex, the number of individual fibres in the cross section of that yarn will be as low as 94.

So, the example cotton yarn has 2.6 times as many fibres in the cross-section as the exemplified flax/cotton yarn.

In addition to that, the inferior quality parameters of the blended yarn are due to the difference in the physical structure and shape between cotton and cottonised flax, to the advantage of cotton [7-10].

#### Examples of the use of flax/cotton yarns with a high content of flax for the production of woven fabrics and other textile products

Below are listed the woven and knitted products manufactured with use of flax/cotton blended yarns with a high content of flax:

- Woven suiting – denim, bleached, area weight - 360 g/m<sup>2</sup>, warp – 40×2 tex, weft - 100 tex;

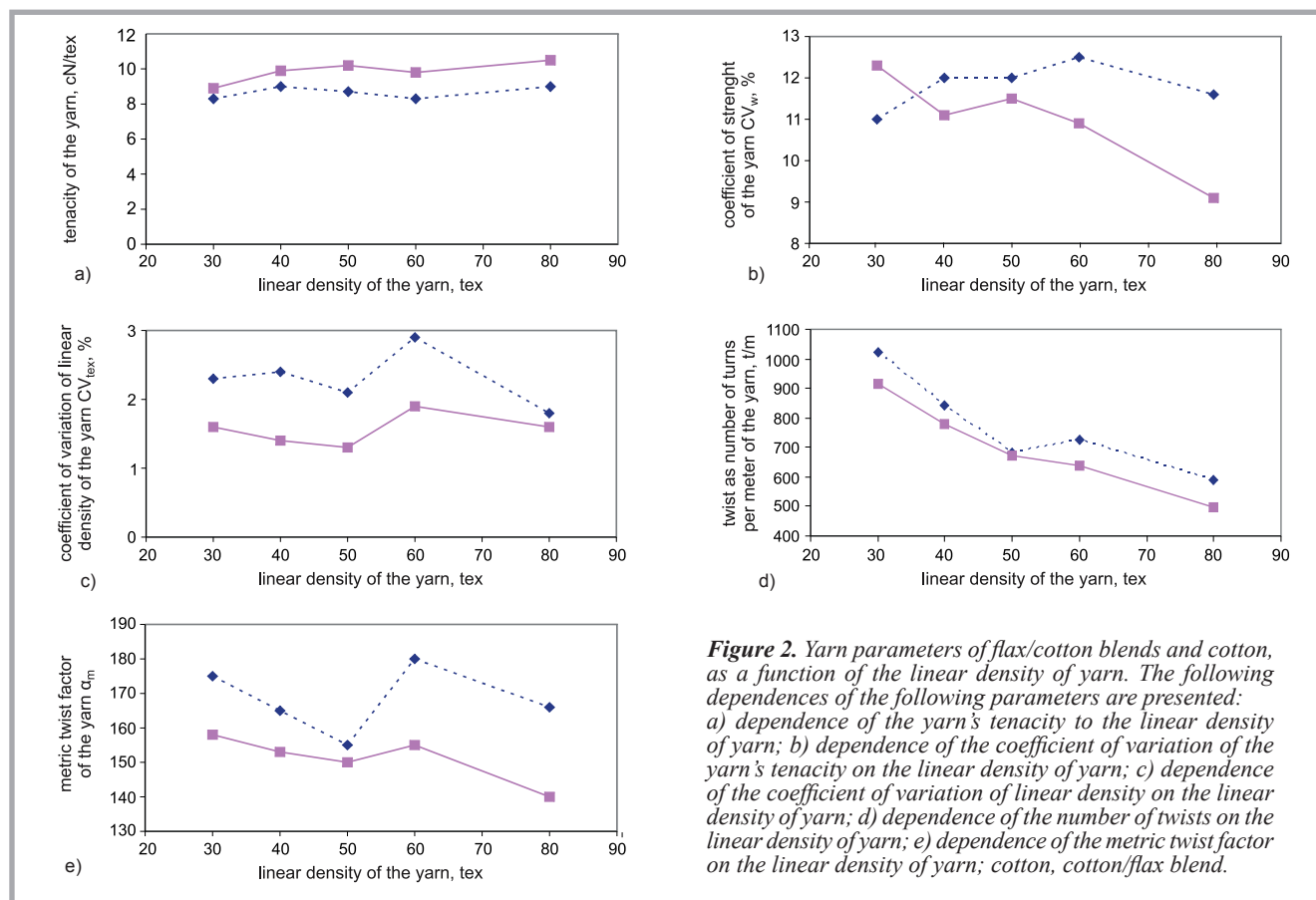


Figure 2. Yarn parameters of flax/cotton blends and cotton, as a function of the linear density of yarn. The following dependences of the following parameters are presented: a) dependence of the yarn's tenacity to the linear density of yarn; b) dependence of the coefficient of variation of the yarn's tenacity on the linear density of yarn; c) dependence of the coefficient of variation of linear density on the linear density of yarn; d) dependence of the number of twists on the linear density of yarn; e) dependence of the metric twist factor on the linear density of yarn; cotton, cotton/flax blend.



- Woven women's suiting in natural colour,  
area weight - 200 g/m<sup>2</sup>,  
warp - 30×2 tex, weft - 40 tex;
- Woven men's suiting in natural colour,  
area weight - 241 g/m<sup>2</sup>,  
warp - 40 tex, weft - 30×2 tex (with addition of Lycra)
- Bed sheeting, bleached,  
area weight - 160 g/m<sup>2</sup>,  
warp and weft - 40 tex;
- Woven fabric for blouses, bleached,  
area weight 145 g/m<sup>2</sup>,  
warp and weft - 40 tex;
- Woven suiting in natural colour,  
area weight - 197 g/m<sup>2</sup>,  
warp - 40 tex, weft - 30×2 tex (with addition of Lycra);
- Knitted underwear fabric in natural colour,  
area weight - 237 g/m<sup>2</sup>,  
perforated yarn - 50 tex;
- Knitted dress goods in natural colour,  
area weight - 230 g/m<sup>2</sup>,  
perforated yarn - 40 tex;
- Sports socks, yarn - 60 tex.

The products mentioned above were produced on a commercial scale in the following Polish factories and enterprises: Zamatex (weaving mill), Moszczenica; Andropol (multi-directional enterprise), Andrychów; Linen Style (knitting enterprise) Poznań; Fabryka Wyrobów Lnianych (weaving mill) Żyrardów; Pawelana (enterprise) Pabianice; Frotex (spinning & weaving mill) Prudnik; Len (enterprise) Kamienna Góra; The Institute of Textile Architecture, Łódź; Lodex (weaving mill), Łódź; Polkonfex (enterprise), Łódź; Artistic Workshop Bartecka; Zwoltex (multi-directional enterprise), Zduńska Wola; Caps (knitting mill), Kraków; Pasmanta (weaving mill), Białystok; Fine Fashion (enterprise), Pabianice; Asia (weaving mill), Łódź.

## Conclusions

The technology developed for rotor-spinning flax/cotton blends with a flax content up to 70% permits the production of cotton-type yarns ranging from 30 to 80 tex. These yarns are suitable for the production of a wide range of woven, knitted and other textile products (e.g. socks).

1. Compared to all-cotton yarns, the blended yarns with flax are characterised by lower strength (about 10% lower) and higher coefficients of variation of linear density and strength. The differences between the two types of yarn are due, inter alia to the fact that cotton is much thinner than cottonised flax, which makes a significant difference as far as the number of fibres in the yarn cross-section is concerned.

In addition to that, cotton, owing to its shape, has a greater suitability for spinning than cottonised flax. It is true, however, that in respect to their quality parameters, the blended yarns satisfy the quality requirements of the relevant standards.

2. To ensure a smooth process when spinning a flax/cotton blend, it is necessary to use a higher twist factor, of the order of 10-12%. As a consequence, the efficiency of spinning proper is reduced.
3. The introduction of cottonised flax to rotor-spinning in a blend with cotton is a contribution to the more effective utilisation of flax, since the cotton system machinery is much more productive.

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